

Symmetries of Space, Time, and Matter

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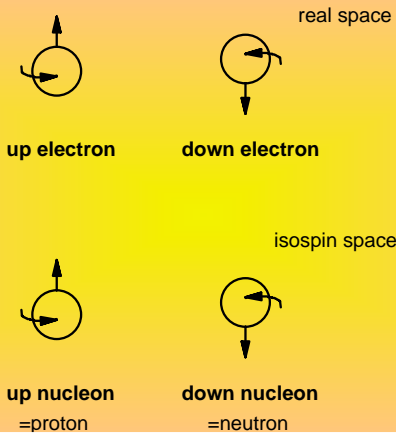
1

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Isotopic Spin



2

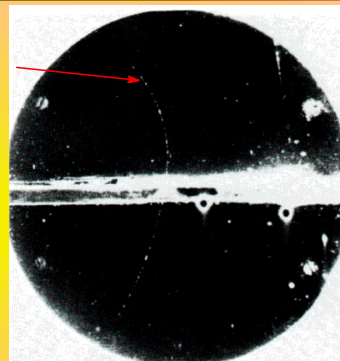
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Charge Conjugation: Particle - Antiparticle

First positron (e^+)
seen in cloud chamber



Path bent by
magnetic field
Bend shows positive charge

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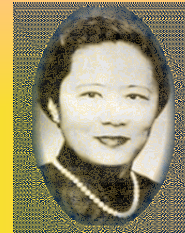
Lee and Yang (1956): "Is Nature Mirror Symmetric?"



T. D. Lee



C. N. Yang



C. S. Wu

"No."

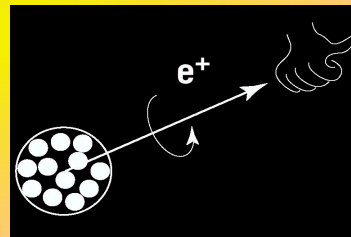
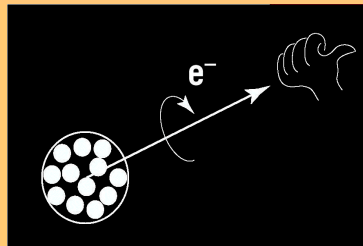
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Parity violated in Beta Decay



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Quarks and Leptons

quarks	u	c	t
	d	s	b
leptons	ν_e	ν_μ	ν_τ
	e	μ	τ

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Left-handed electron and neutrino are partners.

weak isospin space



up left-lepton
=neutrino



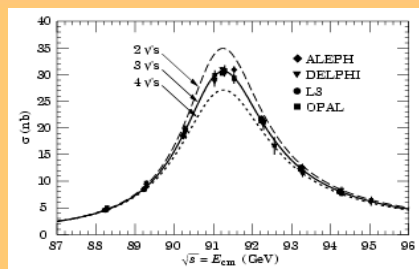
down left-lepton
=electron

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Electroweak Symmetry: Marvelous but Broken



Works great!

*But electrons and neutrinos are
really different.*

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CP not Conserved

Before 1964: CP conserved:

CP-even $K_S \rightarrow \pi^+\pi^-$

CP-odd $K_L \rightarrow \pi^+\pi^-\pi^0$

1964:

$K_L \rightarrow \pi^+\pi^-$
(one time in 2000)



J. Cronin



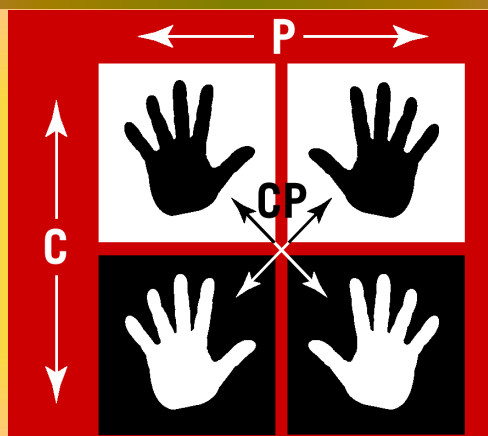
V. Fitch

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Imagining CP Symmetry



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CP conservation makes matter and antimatter cancel



Andrei Sakharov



Matter and antimatter will cancel
like these hands folded over.
Need some misalignment - CP violation

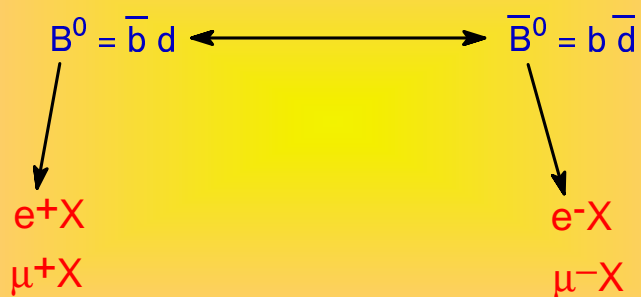
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$B^0 - \bar{B}^0$ Oscillations



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Supersymmetry

- Enlarges space-time symmetry
- "Supersymmetry has withstood the test of time, though there is no evidence to support it"

electron



spin-1/2

selectron ??



spin-0

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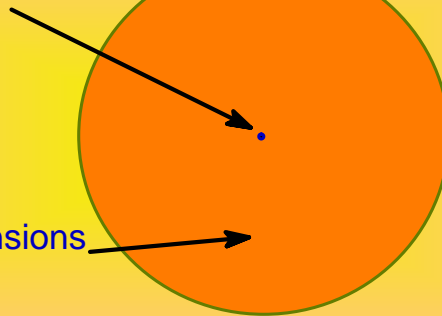
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Extra Dimensions

You are here.



spatial dimensions
4 and 5

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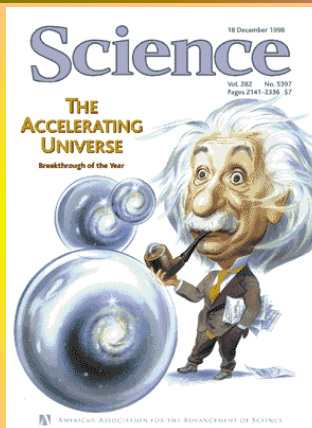
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Accelerating Universe

- Universe filled with "dark matter" pulling in
- Space pervaded by dark energy "pushing out"



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